**Last time I had a look at the steel making industry for this channel, which was about eighteen months ago, I discovered that it was responsible for about seven percent of total global human induced carbon dioxide emissions. That video looked at the substitution of GREEN HYDROGEN into the iron ore reduction process in an attempt to do away with the very carbon intensive coke that was used in blast furnaces. The hope was that by moving over to this new process, steel makers could reduce their carbon dioxide emissions by more than ninety percent.**

**Despite the best efforts of a truly pioneering Swedish company called Hybrit in Sweden, to date there are no full scale industrial steel making plants yet employing the green hydrogen steel making process, and in fact, according to the International Renewable Energy Agency or IRENA, CO2 emissions from steel making industry have moved from about seven percent of the global total, to more like eight percent, not least as a result of China’s industrial recovery from COVID.**

**The lack of adoption of the HYBRIT process reflects the fact that the electrolysis required to produce green hydrogen is currently several times more expensive than the existing method of making hydrogen -a process called Steam Methane Reforming, or SMR, which releases oodles of carbon dioxide into the atmosphere. So, although we will certainly get to a full scale, green hydrogen steel making process in the fullness of time, we most likely won’t get there soon. Probably not for a couple of decades in fact. That means we need to find a slightly more do-able quick fix if we want to really make a dent on steel making emissions in the short term.**

**And now, a group of researchers at the University of Birmingham here in the UK has provided us with a blue print of how that might just be** **achieved.**

**Hello and welcome to Just Have a Think**

**Steel making is one of those so-called ‘hard to decarbonise’ industries that some commentators suggest we should simply not worry about for the moment, and instead we should be throwing all our available resources at the really big emitters like energy, heat and transport. That’s a bit of cop out though, isn’t it? And it’s certainly not the view taken by most operators in the steel industry itself, most of whom seem to be quite keen to find solutions that could genuinely decarbonise their production.**

**According to the authors of this new research paper, seventy one percent of all steel produced today is made using blast furnaces and basic oxygen furnaces. Once the basic iron ore has been dug out of the ground, it has to be reduced into metallic iron. That’s where the blast furnace comes in. Coking coal is added to iron ore and limestone and blasted with air at temperatures of about a thousand degrees Celsius via jets in the base. Oxygen in the air burns the coke at temperatures around sixteen hundred degrees Celsius which reduces the iron ore to iron oxide and then to molten iron, known as hot metal. The limestone reacts with other impurities in the ore to produce a liquid slag that can be skimmed off. The by-products of the process are carbon dioxide and carbon MONOXIDE. For every tonne of molten iron produced in a blast furnace, about one point two tonnes of carbon dioxide are emitted.**

**The resultant molten iron, or pig iron, has a carbon content of about four percent, which makes it very brittle, so it gets transferred into a basic oxygen furnace, or BOF, where a very precisely controlled amount of air is injected in at extremely high pressure. That causes yet more oxygen to react with some of the unwanted carbon in the iron, to produce steel with a carbon content of between one and one and a half percent.**

**The resultant emissions from the overall production process work out at one-point-nine tonnes of Carbon dioxide for every tonne of steel.**

**The team at the University of Birmingham recognised the fact that we’re some way off solving the global steel making emissions problem with green hydrogen. An awful lot of machinery and infrastructure will need to be converted at great expense to move over to the new method and, according to IRENA, the world would need a globally agreed carbon price of about sixty-seven dollars per tonne to make the hydrogen process competitive with the traditional blast furnace, basic oxygen furnace combination. So, the question that the Birmingham team posed was, are we doing everything we can to make the EXISTING process as low carbon as possible? And, given that I’m talking about their findings on this channel, it probably won’t surprise you to learn that their answer was emphatically NO!**

**The insight that the Birmingham team made was to add a perovskite material into the mix to minimise carbon DIOXIDE production - which we know is the main greenhouse gas driving the warming of our atmosphere, and to MAXIMISE carbon MONOXIDE production, which is not a greenhouse gas at all. You may be more familiar with the term perovskite in the context of the extremely encouraging role they appear to be playing in the development of solar photovoltaic cells, which is a subject we’ve looked at in a previous video. In this context, the science bods have used a perovskite material that has this formula, which they have thankfully abbreviated to BCNF1.**

**Now I’m going to read the next section of test as convincingly as I possibly can, to make you think that I might actually know what I’m talking about. But don’t be deceived dear friends. I am about as conversant with the intricacies of perovskites as you probably are. But anyway, just for fun…here goes…**

**BCNF1 is a double perovskite material with a cubic structure, where barium atoms are found at the A-site of the perovskite, calcium, niobium, and iron share the B-sites and oxygen atoms are found at the interstices.**

**Apparently, when this BCNF1 perovskite is heated to seven hundred degrees Celsius, it gives up oxygen from its crystalline structure which creates an oxygen vacancy in that structure. At eight hundred degrees Celsius, any carbon dioxide that happens to be nearby gets split into carbon monoxide, with the extra oxygen atom being used to fill the oxygen vacancy, returning the perovskite back to its original form. Chucking BCNF1 into the furnace has been found to convert more than ten percent of the carbon dioxide into carbon monoxide over the course of five cycles, which when scaled up to industrial levels is calculated to produce carbon monoxide at a cost of nineteen pence per kilogram at an electricity price of eleven pence per kilowatt hour, or, if you could get your electricity price down to five pence per kilowatt, which at the time of publishing the paper was the average price for industry in the United States, then you’d be producing carbon monoxide for just eleven pence per kilogram.**

**The research paper provides us with this rather complicated and confusing diagram to explain how a closed loop BCNF1 thermochemical cycle would work, with inputs of heat and carbon dioxide and outputs of carbon MONOXIDE and oxygen.**

**There are two thermochemical reactors down here. The first one is at seven hundred degrees Celsius to release the oxygen from the perovskite, and the second one reacts that reduced perovskite with carbon dioxide at eight hundred degrees Celsius to produce carbon monoxide. Once those two reactions are complete, the gas flow can be reversed to start the reaction off all over again but in the opposite direction.**

**The carbon monoxide produced in this way can replace ninety percent of the coke in the blast furnace, with the remaining ten percent coming from biomass-based charcoal or even recycled plastics to provide a source of carbon.**

**Now, there’s an awful lot more science outlined in the paper that explains things like mass flows, heat fluctuations and the number of moles of each component, to fully explain every single step in this diagram. Much of that is well beyond the scope of this video, but if you really want to dive into the minutiae then I’ve linked the paper in the description box below, and its open access too, so it won’t cost you anything to go and have a look. The Birmingham team calculated that overall, this technique, which they describe as the TC-BF-BOF system, would reduce carbon dioxide emissions by ninety-four percent compared to a typical blast furnace / basic oxygen furnace set up, with the only emissions coming from the biomass-based charcoal right at the start of the process.**

**The obvious practical advantage of a TC-BF-BOF set up is that you can continue to use existing blast furnaces and basic oxygen furnaces, which means the steel industry wouldn’t be faced with a bunch of expensive stranded assets. It also means the preservation of highly skilled jobs and possibly even the creation of new jobs in the industry as part of the management and operation of the thermochemical reactors. Plus you get an immediate reduction in emissions as soon as the new kit is bolted on, rather than waiting years for brand new technologies to come into reality. Economic analysis apparently shows that implementing this system could save the UK steel industry nearly one point three billion pounds over five years and reduce the UK’s overall greenhouse gas emissions by almost three percent.**

**PAUSE…**

**Right..bit of a wrinkle. As you probably know, this channel’s Patreon supporters get early access to all these videos before you good folks out there in YouTube land get to see them. It acts as a bit of a filter to weed out any errors or inaccuracies in my research, which means you hopefully get content that is as accurate and realistic as possible. One of those Patreon supporters just happens to have specific responsibility for developing green steel decarbonisation pathways for one of the world’s largest metallurgical plant suppliers, and..well let’s just say, he had a bit of feedback to offer! No names, no pack drill, but here goes…**

**Apparently, replacing all the coke in the blast furnace with any gas is not quite so easy in real world production as the authors of this paper have suggested. Coke has far more permeability for the reducing gases, and the physical crush strength of the coke itself as well as its high melting point help to stabilise the various materials in the mix and maintain movement towards the bottom where the hot metal can then be collected. The mixture of iron ore, coke and slag forming fluxes is something the industry refers to as ‘burden’. Without the right mx and ratio of materials in the burden, the incoming gases could flood the furnace and stall the downflow of molten iron and slag, potentially costing huge sums of money to rectify.**

**Then there’s the perovskite. Usually, catalyst absorbers like this are very sensitive to gas qualities which means they can become poisoned by the gases they absorb, making the normal practice of recovering**  **Iron and steelmaking gases for a variety of other industrial applications quite hazardous. To get round that problem, a very intensive process known as ‘gas cleaning’ would be needed in real-world, full-scale production to keep the perovskite working effectively, and that of course is yet another very costly additional step. Now, the authors of this paper do say that research is still required to investigate the effect of coke removal on structural stability, but they don’t appear to have factored that into their headline claim of a near ninety percent reduction in industry CO2 emissions. That doesn’t mean their research is completely wrong, but it probably means a great deal more work will be required before this approach becomes a commercial reality.**

**Oh, and just a note about SSAB and Hybrit. I should say that they are not alone in their drive towards the green hydrogen solution I mentioned at the start of the video. Another firm called H2GS is in the process of constructing the first commercial scale hydrogen direct iron reduction plant, capable of producing two point one million tons of reduced iron per year, and completely electrifying steelmaking, casting, rolling, and processing of steel. That plant is due to be in service by the end of twenty-twenty-five. And there are a number of similar projects across Europe, for example GravitHy in the South of France and Blastr in Norway.**

**So, there we are then folks. You live and learn, eh? YOU may even have OTHER information that you can contribute to this particular topic, so I’ll brace myself and head down to the comments section below to see what else I can discover.**

**An extra special thank you then, to the Patreon supporter who provided me with such important feedback, and a big thank you to all of you folks too for watching this video all the way to the end. I really do appreciate it.**

**Have a great week, and remember to Just Have a think.**

**See you next week**